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REDUCING SEED LOSSES AND FUEL CONSUMPTION IN RAPESEED HARVEST

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Abstract. Rapeseed harvesting starts in the Baltics as soon as seed moisture content decreases to 12%. While the variation in seed moisture content is not affected by short-term precipitation, prolonged precipitation leads to ca. 2% increase in the moisture content. 0.2 m high stubble of winter rapeseed accounts for the share of 49.87% in the total stem mass. Its moisture content is 10.39% higher than of the remaining share of the stem mass. Increase of the stubble height to 0.3 m leads to 15.52% reduction in the stem mass fed into a combine harvester, and 1.79% reduction in moisture content of the stem mass. In this case, fuel consumption per hectare of harvested rapeseed is lower by 2.74 l, and per ton of threshed seeds – by 0.27 l. Relationship between the rate of rapeseed feed into a combine harvester, shatter loss from straw separation and chaff cleaning, and fuel consumption per ton of threshed seeds has been found. The rate limit of rapeseed feed into the combine harvester is reached, when fuel consumption per ton of threshed seeds has stopped reducing, but shatter loss from straw separation and chaff cleaning is still within the tolerable range. In the case of winter rapeseed harvesting under processing conditions, fuel consumption per ton of threshed seeds ranged from 2.5 to 6.5 l, while in the case of rational rate of rapeseed feed into the combine harvester, fuel consumption per ton of threshed seeds reached 2.93±0.23 l.

Key words: combine harvesters, rapeseed, fuel consumption, grain loss, throughput.

Introduction

Rapeseed oil is used in food industry, biofuel, rapeseed cake – for production of compound feed, and straw – for production of solid fuel. In Europe winter rapeseed varieties [1] are preferred to summer varieties due to higher yield of the former. In Lithuania, winter rapeseed areas account for the share of 80,5% of the entire rapeseed crop area [2]. Winter rapeseed yield is 1.7 times higher compared to summer rapeseed.

Winter rapeseed crops are harvested during the third ten-day period of July, while summer rapeseed harvesting takes place at the end of August, when average moisture content of seeds is ca. 12% [3]. Natural factors may lead to shatter losses of up to 2.5 %, whereas delay of reaping may result in as high as 6.8 % shatter loss [4]. Natural shatter losses are affected by genetic properties of the rapeseed [5, 6], short-term heavy precipitation and strong wind [7]. Shatter loss may be reduced biologically and chemically by speeding up the process of rapeseed maturation or delaying the dehiscence of siliquae.

Formulation of problem

Moisture content of stems during the rational rapeseed harvesting period reaches 75–85 % and reduces slowly. Stem branches are usually covered with abundant foliage. Shatter loss from combine harvesting may account for up to 11 %, natural shatter loss – 3% [8].

Maturation of siliquae varies depending on their location on the rapeseed stems: higher location determines earlier maturation, while siliquae located lower are prone to delayed maturation. Dehiscence of siliquae occurs naturally and their seeds fall on the soil before all siliquae become mature [4]. The crops are sprayed with Pinolen solution to reduce the natural shatter loss [9]. Siliquae are coated by the light film of viscous solution that prevents them from opening. Natural shatter loss of the rapeseed crops sprayed with Agrovital solution was 7 %, compared to 26% of the shatter loss in case of unsprayed crops [10]. In the cases of very unfavourable conditions during rapeseed harvesting, shatter loss from harvesting the rapeseed sprayed with Pinolen solution was 11 times as low as for the unsprayed rapeseed [11].

Analysis of recent research results

Combine harvester throughput and performance during rapeseed harvesting largely depend on the moisture content of rapeseed, rate of the mass fed into the combine harvester and composition of the mass [12, 13]. Values of diameter, moisture content and mass increase the closer to the soil, compared to the values at the top branches [14]. As long as the rapeseed has not flattened, it may be harvested by leaving higher stubble. Combine harvester throughput has been determined to increase by 1.5–2 %, and fuel consumption – to decrease by 1.5 % with each 10 mm added to the crop stubble height [15, 16]. On the other hand, the rapeseed is more humid in the morning and evening, leading to smaller running speeds of combine harvesters and resulting in higher fuel consumption per ton of threshed seeds. Pattern of variation of fuel consumption during rapeseed harvesting in the course of the day in different years has not been determined yet. Biometric indicators of winter and summer rapeseed are different, and their effect on the performance indicators of combine harvesters and fuel consumption has not been revealed yet.

Purpose of research

The aim of the study is to validate rational means for reduction of shatter loss from combine harvesting of rapeseed and fuel consumption.

Results of research

Biometric indicators: For the purpose of identification of the biometric parameters, the number of plants and number of siliquae of each plant, the height of stems, distance from the soil to the first branch were determined in plots of 0.25 m^2 in five replicates sampled randomly on production fields of farms before rapeseed harvest (*BBCH88*). Siliquae picking from different locations of the site was repeated three times with 50 siliquae picked each time. Length of each siliquae, number of seeds per siliquae, seed weight and the mass of 1000 seeds were determined at the laboratory. Stems of rapeseed were taken from five replicates of 0.25 m^2 to determine the biological rapeseed yield. The stems were then transferred into individual waterproof bags of large volume. Each sample was hand-threshed at the laboratory. Clean seeds, chaff, stems, and 0.2 and 0.3 m high stubble were weighted individually. Samples of rapeseed stems, stubble and seeds were taken to determine the moisture content. Samples were subjected to drying at 105 ºC to the steady moisture content condition. Biological yield of the rapeseed and share of stubble in the straw mass were calculated. Average data were calculated. The mass of all sample seeds was calculated at 9% moisture content.

- Natural shatter loss. Variation in moisture content and natural shattering of seeds of winter rapeseed variety Sunday was observed at the Experimental Station of Aleksandras Stulginskis University. On 30 July, seven 1.5 x 0.05 m troughs were placed on the site of the rapeseed crops. The inner surface of the troughs was coated with waterproof and cloth of low elasticity. The troughs were checked for shattered seeds on the daily basis at 2 p.m.; seeds found in each trough were counted, put into bowls and weighted at the laboratory. Siliquae were picked in a separate part of the site alonthe stems of the rape, hand-threshed, and five samples of seeds were taken to determine the moisture content. Average moisture content of seeds and shatter losses of seeds of 9% moisture content in kg ha^{-1} were calculated on the daily basis.

- Variation of moisture content and weight along the stems. Rapeseed was cut near the soil at the monitoring site of the five plots of 0.25 m^2. Each sample was subjected to individual threshing. The stems were cut into 100 mm long pieces. Each length class of the pieces was weighted. The pieces were then cut into smaller pieces of up to 10 mm in length, and five samples were taken to determine their moisture content. Moisture content of each length class of stems and their share in the total mass of stems were calculated.

- Shatter loss from rapeseed straw separation and chaff cleaning. Determination of the loss was carried out at the production fields of farms during rapeseed harvesting by combine harvesters of different designs. For this purpose, 0.0213 m^2 bowls having the shape of a cut cone were used. Rapeseed samples to determine the biometric indicators were taken from five 0.25 m^2 plots of 100 m long field section of unflattened crops of uniform density and maturity.

The researchers communicated with the supervisor of research programme sitting in the cabin of the combine harvester via RC during the operations. Two bowls were placed under the combine harvester moving at the programme speed and distributing the shredded straw, one – next to the driving wheel, other bowls – at the distances of one meter from the wheel (width *b* of the stretch of the distributed cut straw had to be taken into account). Afterwards, rapeseeds in the bowls were calculated. Moisture of the seeds was measured using Pfeuffer HE lite moisture meter (accuracy of readings – 0.1%). Shatter loss from rapeseed straw separation and chaff cleaning was calculated in kg ha^{-1} as follows:

$$N = \frac{aAb}{2{,}13B},$$

where a – average number of seeds per bowl, pcs., A – mass of 1000 seeds, g; B – cutting table width of the combine harvester, m; b – width of the stretch of the distributed cut straw, m.

The mass of 1000 seeds distributed into ten samples (100 seeds each) was determined under field conditions using Kern CM320 scales. The mass ranged from 3.7±0.13 to 4.8±0.035 g.

Where the seeds in the bowls were weighted under field conditions using the scales (*Kern CM320*), shatter loss was calculated in kg ha^{-1} as follows:

$$N = \frac{469{,}5a_1b}{B},$$

where a_1 – average mass of seeds in the bowls, g.

- Combine harvester throughput. Distance made by the combine harvester and its fuel consumption were registered at the beginning of the operations. Filling time of each hopper, distance made by the combine harvester, seed yield, and moisture content were registered during the operations. Moreover, seed discharging time of each hopper was measured under the conditions of standstill and running combine harvester. Seeds of each hopper were weighted at the warehouse. Where a combine harvester was not equipped with any seed moisture content and yield meter, moisture content was determined using a portable moisture meter, while average yield was calculated according to biometric indicators of the harvested crops.

Combine harvester throughput during the process time (ha h^{-1}) was calculated as follows:

$$W = 0{,}1BvT,$$

where: B – cutting table width, m; v – combine harvester running speed, km h^{-1}; T – operating time, h.

Combine harvester throughput during the process time (t h^{-1}) was calculated as follows:

$$W_1 = \frac{3600\,G}{T_1},$$

where: G – hopper grain mass, t; T_1 – hopper filling time, s.

- Fuel consumption. Fuel consumption by combine harvester C was measured in l h^{-1} using AIC-888 Instructor device produced by the Swiss company Automotive Information and Control Systems AG. Verification of the device was in compliance with Euro-Norm 95/54/CE. Measurement tolerance: ±1%. Fuel consumption by combine harvester E was measured in l h^{-1} using the manufacturer's device. Real-time fuel consumption readings were shown on the computer display. Average fuel consumption per ton of threshed seeds and hectare of harvested rapeseed was calculated based on the values of filling time of each hopper, seed mass and fuel consumption measured at factory conditions. The obtained data were more accurate, where harvesting of each rapeseed variety was monitored individually from early morning to late evening for several days.

- Statistical analysis. The experiments of rapeseed shattering were carried out in 7 replicates, whereas others – in 3 replicates. One-way analysis of variance (*ANOVA*) was performed with MS Excel to analyse the data. Significant difference ($p<0.05$) between treated and non-treated rapeseed was determined with Fisher's LSD range test.

- Grain combine harvesters. Throughput, shatter loss from straw separation and chaff cleaning, fuel consumption were measured for winter and summer rapeseed harvesting by combine harvesters with straw walkers *A* and *C*, hybrid combine harvester *D* and combine harvester with two axial threshing-separation cylinders *E*.

Combine harvesters *A* and *C* are of average, while *D* and *E* are of high throughput. The main threshing cylinder in combine harvesters *A*, *C* and *D* is preceded by a cylinder of 0.45 m in diameter that accelerates the throughput speed of the inclined conveyor from 5 to 15 m s^{-1}. As a result, thinner layer of mass is fed into the threshing unit. Harvesting of winter rapeseed was carried out in different years in July and August. Biometric indicators and variation of moisture content along the length of stems were measured at the laboratory, while combine harvester throughput, shatter loss and fuel consumption – during rapeseed harvesting.

1. Weather condition. Starting time of winter rapeseed harvesting is largely affected by weather conditions of July. There were 16 rainy days in July and 11 rainy days in August on average leading to > 0.5 mm precipitation.

2. Biometric indicators of rape Operating speed and performance indicators of a combine harvester are determined by the rate of rapeseed feed and its composition. It was determined that the density of different varieties of winter rapeseed crops were within the data distribution range (Table 2). The height of stubble during rapeseed harvesting is limited by the distance from the soil surface to the first branch. Unflattened winter rapeseed may be cut by leaving the stubble of ca. 0.3 m in height.

2. Starting time and period of rapeseed harvesting. Rapeseed cutting starts after decrease of seed moisture content down to 12% (Fig. 1). Where weather conditions are favourable for rapeseed maturation, seed moisture content decreases down to 8.5% within three days, in which case desiccation is not required.

Table 1. The key technical data of combine harvesters.

Indices	Measuring units	Combine harvester			
		A	*C*	*D*	*E*
Header width	m	6	6	9.1	7.3
Cylinder (rotor) diameter	m	0.45	0.6	0.6	0.559
Cylinder (rotor) length	m	1.58	1.7	1.7	2x2.638
Total separation area of concaves	m^2	1.32	1.73	1.73	3.06
Total separation area of sieves	m^2	5.65	5.8	6.2	6.5
Grain tank capacity	l	9000	8100	12000	10500
Engine power	kW	220	203	368	360

Table 2. Biometric indicators of winter and spring rapeseed.

Index	Measurement unit	Winter rape		
		Catalina	Sunday	Remy
Crop Density	(st. m^2)	43.20±4.91	45.3±2.8	45.2±6,11
Height of plants	(m)	1.27±0.05	1.24±0.05	1.29±0.04
Distance from soil surface to first branch of plant	(m)	0.47±0.11	0.41±0.07	0.25±0.06
Stubble mass (250 mm) share in total stem mass	(%)	44.96±6.27	56.15±2.14	34.05±0.6
Length of siliquae	(mm)	72±3.40	61.73±0.79	72.03±1,71
Number of seeds within siliquae	(units)	26.5±2.1	25.35±1.23	27.4±0.73
Weight of seeds within siliquae (9%)*	(g)	0.105±0.01	0.114±0.01	0.121±0,01
Weight of 1000 seeds (9%)*	(g)	3.7±0.13	4.8±0.035	4.74±0.03
Biological yield (9%)*	(t ha^{-1})	2.74±0.77	5.25±0.44	3.41±0.39

*Seed moisture content

Dry rapeseeds react to variations of ambient atmospheric conditions. Although no precipitation was registered on 5 August, moisture content of seeds increased by ca. 1 % within two days due to increase of relative humidity of ambient air by 10 %. Mature rapeseed must be cut within three days, or harvesting may continue to the first heavier rain (> 3 mm). Light precipitation (0.1 mm) did not affect variation in seed moisture content (11 August).

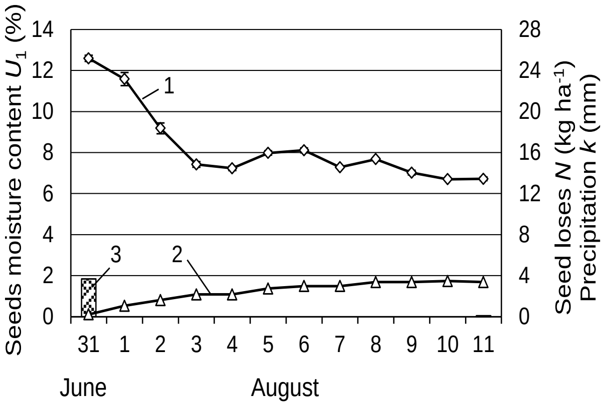

Fig. 1. The dynamics of seed moisture content (U_1) and total shatter losses (N) of winter rapeseed variety Sunday for particular days of July and August, 2009: 1 – seed moisture content, in %; 2 – total shatter losses, in kg ha^{-1}; 3 – precipitation.

4. Stubble height. In case of harvesting of fully flattened rape, 0.1 m of stubble is left, while in case of unflattened rapeseed, the stubble height is 0.2 to 0.3 m.

During harvesting of rapeseed variety Catalina, seed moisture content reached 9.21%, while moisture content of the total stem mass was as high as 75.33%. The share of stubble (0.2 m in height) was 39.42±2.56% of the total stem mass, moisture content of the stubble reached 82.33±0.68%, while moisture content of the mass fed into combine harvester was as high as 71.96±1.78%. After the stubble height had been increased to 0.3 m, 11.86±0.82% less stem mass was fed into the combine harvester, and its moisture content was lower by 1.18 %.

Stubble (0.2 m) of winter rapeseed variety Sunday accounted for the share of 47.3±1.59% in the total stem mass, where seed moisture content reached 17.25, while the average moisture content of stems was 80.43%. The higher the moisture content of harvested rapeseed, the larger the share of stubble mass in the total mass. After the stubble height had been increased to 0.3 m, 13.61±0.61% less stem mass was fed into the combine harvester, and its moisture content was lower by ca. 2.44 % points.

In general, taking into account the dynamics of mass of different winter rapeseed varieties in 2009–2012 at the specific length of stems (0.6 m), close relationship between stubble height h and its mass m_1 has been determined:

$$m_1 = 107.23h^2 – 98.55h + 33.45, R^2 = 0.97.$$

Variation in the moisture content along the rapeseed stems is poor. Linear dependency between stubble height h and its moisture content U_2 has been determined:

$$U_2 = -17.97h + 85.13, R^2 = 0.99.$$

5. Shatter loss from rapeseed harvesting. During harvesting by combine harvesters, seeds fall out of active side dividers of the cutting table, reels that have been lowered excessively or are subject to excessively fast rotation. An operator of the combine harvester may reduce the shatter loss from rapeseed harvesting by changing the reel position, the ratio between their rotation speed and running speed of the combine harvester. In case of irrational rapeseed feed into the combine harvester, straw walkers or rotary straw separators and cleaning sieves fail to separate all seeds from the chaff. Combine harvesters still lack a reliable meter of shatter loss from straw separation and chaff cleaning. As a result, shatter loss from straw separation and chaff cleaning is determined manually, with subsequent adjustment of computer readings.

The effect of the rate of winter rapeseed feed into combine harvester ***A*** of average throughput on the shatter loss from straw separation and chaff cleaning has been analysed (Fig. 2). The lowest number of seeds that had dropped on the soil together with straw and chaff was registered during rational feed rate of rapeseed into the combine harvester.

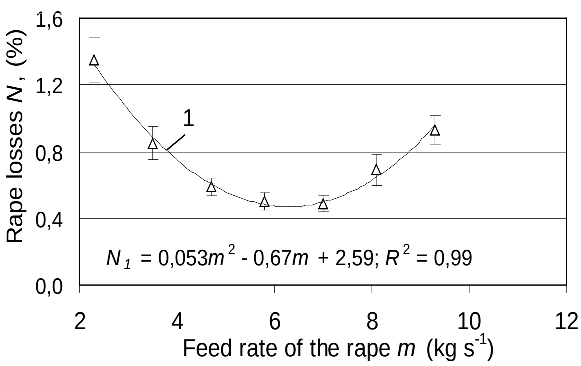

Fig. 2. The effect of the rate of rapeseed feed into combine harvester A on shatter loss from straw separation and chaff cleaning: 1 –winter rapeseed Catalina: rotation speed of the threshing cylinder n_b=740 min^{-1}, rotation speed of the ventilator n_v=750 min^{-1}, clearance between the cylinder and sub-cylinder a=20-121 mm, clearances between sieve scale in the upper sieve b_1=6 mm, in the bottom sieve – b_2=2 mm, stubble height h=0.3 m, seed yield A_g=2.84 t ha^{-1}, seed moisture content U_1=9,21%, stem moisture content – U_2=71,96 %.

In case of harvesting of moist winter rapeseed Remy (U_1=14.16%) by hybrid combine harvester D (Fig. 3) of high throughput, and dry rapeseed Casino (U_1=8,8%) by combine harvester with two axial threshing-separation cylinders E, the lowest shatter loss from straw separation and chaff cleaning was determined to be within the tolerance limit of 1 %, when rational feed rate of rapeseed into combine harvester D was 7.58, and in combine harvester E – 12.6 kg s^{-1}. The difference was due to design properties of the combine harvesters and differences in rapeseed moisture content. Shatter loss tended to increase upon reduction or further increase of the rate of rapeseed feed into the combine harvesters. Shatter loss had to be measured manually more frequently at the beginning of rapeseed harvesting in order to validate the rational combine harvester running speed, i.e. the rate of rapeseed feed.

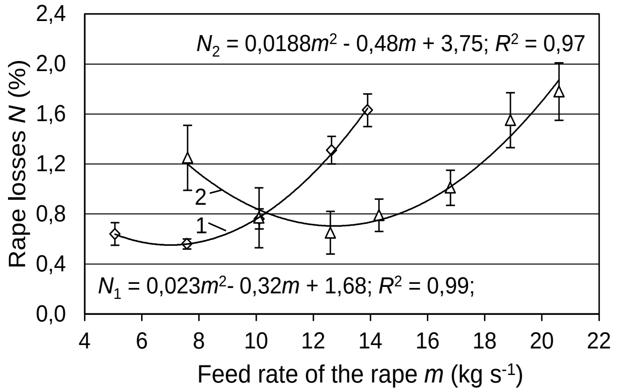

Fig. 3. The effect of the rate of rapeseed feed into the combine harvester on shatter losses from straw separation and chaff cleaning: 1 – combine harvester *D*, winter rapeseed Remy, n_b=560 min^{-1}, n_v=800 min^{-1}, a=18 mm, b_1=12 mm, b_2=5 mm , A_g=3.2 t ha^{-1}, U_1=14.16%, U_2=60.61%; 2 – combine harvester ***E***, winter rapeseed Casino, n_b=650min^{-1}, n_v=500 min^{-1}, a=23 mm b_1=6 mm, b_2=3 mm, h=0.3 m, A_g=3.2 t ha^{-1}, U_1=8.8%, U_2=47.70%.

It has been determined based on research results that, in general, rational rate of rapeseed feed into a combine harvester depends on combine harvester throughput, biometric indicators of rapeseed, and stubble height. In the case of rapeseed harvesting using part of the width of the cutting table or at varying stubble height, running speed of the combine harvester must be adjusted as well in order to maintain the same rational rate of rape feed. The combine harvester should be equipped with an automatic control system that changes process parameters of the threshing unit, straw separator, and cleaner.

6. Fuel consumption and combine harvester throughput. As the combine harvester is cutting the rapeseed and increasing the stubble height (Fig. 4), the mass is fed into the combine harvester at lower rate, leading to less fuel consumed for threshing of one ton of seeds. The reduction in fuel consumption is slightly slower in case of higher stubble due to uneven variation of mass and moisture content along the stems. Where unflattened winter rapeseed was harvested, the most rational height of the stubble was 0.3 m.

It has been determined (Fig. 5) that, with the increase of the rate of winter rapeseed feed into the combine harvester to 12 kg s^{-1}, fuel consumption per ton of threshed seeds saw reliable reduction. Where the rate of rapeseed feed into the combine harvester was exceeded, fuel consumption did not drop and ranged within the tolerance limits. There is certain relationship between rational rate of rapeseed feed, shatter loss and fuel consumption per ton of threshed seeds. Computer of the combine harvester fails to show reliable data on the dynamics of shatter loss; therefore, its automatic speed control should be linked to the engine load and fuel consumption per ton of threshed seeds.

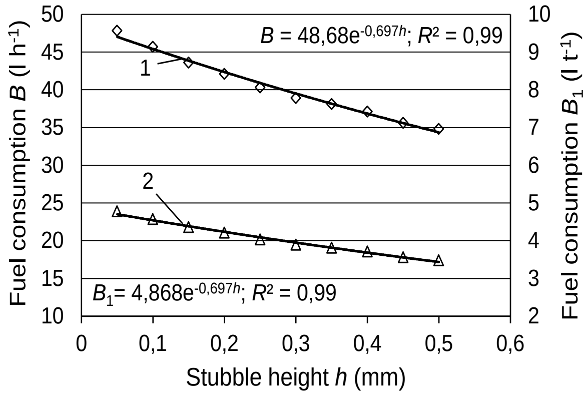

Fig. 4. The effect of the stubble height of winter rapeseed Sunday on fuel consumption per hour (*B*) and ton of threshed seeds (B_1) by the engine of combine harvester *C*: n_b=600 min^{-1}, n_v=930 min^{-1}, a=18 mm b_1=9 mm, b_2=5 mm, A_g=2.3 t ha^{-1}, U_1=11,2 %, v=6 km h^{-1}; 1 – hourly fuel consumption; 2 – fuel consumption per ton of threshed seeds.

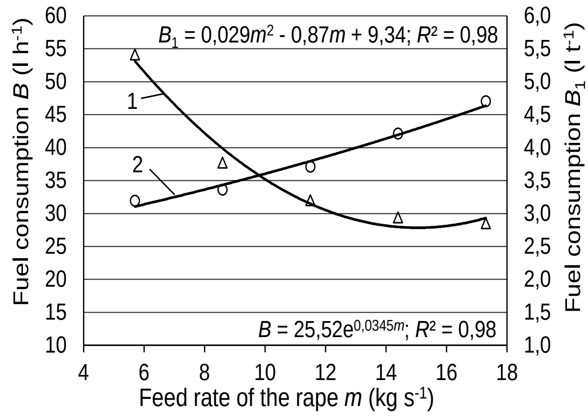

Fig. 5. The effect of the rate of winter rapeseed feed into combine harvester *C* on fuel consumption per hour (*B*) and ton of seeds threshed (B_1) by the engine: h=0.3 m, n_b=600 min^{-1}, n_v=930 min^{-1}, a=18 mm, b_1=9 mm, b_2=5 mm, A_g=2.3 t ha^{-1}, U_1=11,2%; v=6 km h^{-1}; 1 – hourly fuel consumption; 2 – fuel consumption per ton of threshed rapeseed.

Actual fuel consumption was determined more accurately by monitoring combine harvester operations throughout the day or for several days on the production areas. Reliable effect of the time of day during winter rapeseed Visby harvesting on combine harvester *C* throughput and fuel consumption per ton of threshed seeds has not been determined. Combine harvester throughput was slightly higher, and fuel consumption – lower at noon.

Operating conditions may have greater effect on fuel consumption by the engine than change of the fed rapeseed flow in individual cases. Similar data have been obtained for rapeseed harvesting by combine harvester *D.*

Characteristics of winter rapeseed species Visby, Rohan and Cult did not have any reliable effect on combine harvester *C* throughput and fuel consumption. For winter rapeseed Rohan harvesting, fuel consumption per ton of threshed seeds reached 2.54±0.18, while for rapeseed species Cult – 2.22±0.47 l. For winter rapeseed

Remy harvesting by combine harvester *D* under unfavourable conditions, fuel consumption per ton of threshed seeds ranged from 4.4 to 6.9 l. A lot of time at the beginning of harvesting was spent on empty trips and frequent downtimes. Although short-term and heavy precipitation led to shorter operating times of combine harvesters, throughput per net operating time did not reduce.

Discussion

Starting time of rapeseed harvesting and shatter loss are largely affected by weather conditions. Short-term precipitation does not affect moisture content of mature summer rapeseeds [4]. Similar results have been obtained by monitoring the dynamics of moisture content of winter rapeseeds Sunday (Fig. 1) Heavy precipitation (18 mm) leads to increase in moisture content of rapeseeds by ca. 2 %; however, the moisture content drops to the previous value the following day [3]. Prolonged rainy periods lead to increase in total shatter loss several fold [7]. The authors have noted that not only precipitation, but also strong wind > 5 m s^{-1} have greater effect on shatter loss. Under favourable weather conditions, rapeseed harvesting may start as soon as the rapeseed moisture content reaches 9, and in case of rainy weather – 12%. Duration of rapeseed harvesting: 3-5 days.

Combine harvester performance and fuel consumption depend on the rate of rapeseed mass feed into the combine harvester [12, 13]. The rate may be adjusted by leaving higher stubble without any changes to the running speed of the combine harvester. In Germany, moisture content of the mature rapeseed has been found to vary by 70 to 20 % along the length of stems [14], while in case of high moisture content (59.55%), the variation was 10% points only. In Lithuania, relative air humidity in July for the recent decade has been 75.7, August – 79.3%. Moisture content of winter rapeseed Catalina ranged from 83.17±1.88 to 74.10±0.47 the length of 0.6 m high stems. The rate of rapeseed mass feed into the combine harvester and average moisture content may be reduced by increasing the height of stubble. Increase of wheat stubble height from 0.1 to 0.2 m has been found [16] to reduce fuel consumption per harvested hectare by 4 l. According to other authors [15], combine harvester throughput increases by 2 % points with each 0.01 m of added stubble height. On the other hand, the effect of stubble height on performance indicators of the combine harvester has not been covered, while rapeseed harvesting has not been mentioned at all.

Rapeseed is usually harvested by leaving 0.2 m high stubble. Increase of stubble height of winter rapeseed to 0.3 m leads to ca. 15.52 % reduction in the mass of stems fed into the combine harvester and 1.2 % reduction in its moisture content.

Rational rate of mass feed is different for each group of combine harvesters. Therefore, where shatter loss from straw separation and chaff cleaning is within the tolerance limits, change of stubble height must be performed with reference to a combine harvester running speed as well, in order to maintain the rational rate of rapeseed feed into the combine harvester.

Fuel consumption per hour and per harvested hectare provide only partial picture of the operating conditions of combine harvester and engine load. Fuel consumption per ton of threshed seeds provides more accurate actual indicator of combine harvester performance. Increase of the rate of rapeseed feed into the combine harvester to a rational value has been found to lead to reliable drop in fuel consumption per ton of threshed seeds. If rational feed is exceeded, fuel consumption stops reducing and either ranges within the tolerance limits, or starts increasing. There is reciprocal relationship between the rapeseed feed rate, shatter loss and fuel consumption per ton of threshed seeds. As the computer of combine harvester does not show reliable dynamics of shatter loss, automatic control of running speed should be linked to the engine load and fuel consumption per ton of threshed seeds.

During rapeseed harvesting, part of the day is spent on empty trips by a combine harvester on the field, turns at the end of the field, waiting for grain transportation vehicles or repairs. Therefore, actual fuel consumption is higher than fuel consumption during the process time. Fuel consumption by combine harvester *C* per ton of threshed seeds per process time was determined at 2.54±0.18 under favourable conditions and 4.72±0.4 l under unfavourable conditions. No reliable difference in variation of fuel consumption between different species of harvested rapeseed has been found.

Conclusions

1. If the stubble height of winter rapeseed was 0.2 m, the stubble amounted to the share of 49.87% of the total stem mass. Increase of the stubble height to 0.3 m led to reduction of the stem mass fed into the combine harvester by ca. 15.52%, of fuel consumption per hectare harvested – 2.74, per ton of threshed seeds – 0.27 l.

2. The lowest value of shatter loss from straw separation and chaff cleaning was reached in case of rational rate of rapeseed feed into the combine harvester. Contrary to grain harvesting, reduction of rate of rapeseed feed into the combine harvester leads to increased shatter loss. Therefore, when the stubble height is increased, combine harvester running speed must be adjusted to maintain the rational feed rate of the mass.

3. Increase of the rate of rapeseed feed into the combine harvester to a rational value leads to reduction of fuel consumption per ton of threshed seeds, and, further, the fuel consumption either becomes stable or starts to increase. Automatic control of the process of combine harvester must be linked to the engine load and fuel consumption per ton of threshed seeds.

References

1. *Rathke, G.-W., Behrens, T., Diepenbrock W.* (2006). Integrated nitrogen management strategies to improve seed yielg, oil content and nitrogen efficiency of winter oilseed rapeseed (Brassica napus L.). Agriculture Ecosystems & Environment. Nr.117. 80-108.

2. *Statistical* yearbook of Lithania. (2013). 671.

3. *Špokas, L. Velička, R., Rimkevičienė, M., Marcinkevičienė R.* (2005). Ripening dinamics and natural falling of spring rapeseed seeds. Agricultural Sciences. Nr. 3. 29-38. (in Lithania).

4. *Špokas, L., Velička, A., Marcinkevičienė, R., Domeika R.* (2004). Optimierung des Erntezeitpunktes von Sommerraps durch die Sortenwahl. Die Bodenkultur. Bd. 55, H.3. 113-120. (in Germany).

5. *Morgan, C. L., Bruce, D. M., Child, R., Ladbrooke, Z. L., Arthur, A. E.* (1998). Genetic variation for pod shatter resistance among lines of oilseed rapeseed developed from synthetic B. napus. Field crops Research Nr. 58. 153-165.

6. *Šidlauskas, G., Bernotas, S.* (2003). Some factors affecting seed yield of spring oilseed rapeseed (Brassica napus L.). Agronomy Research. Nr. 1(2). 229-243.

7. *Pahkala, K., Sankari, H.* (2001). Shatter loss as a result of pod shatter in spring rapeseed and spring turnip rapeseed in Finland. Agrikultural and food scince in Finland. Vol. 10. 209-216.

8. *Price, J., S., Hobson, R. N., Neale, M. A., Bruce, D. M.* (1996). Shatter losses in Commercial Harvesting of Oilseed Rape. Journal of Agricultural Engineering Research. (65), 3. 183-191.

9. *Rademacher, T.* (2003). Methodology for measuring of quality and loss-throughput behavior for combine harvesters under field conditions. VDI-MEG Kolloquium Landtechnik. Mähdrescher. 40, 83-94. (in Germany).

10. *Rathke, G.-W., Behrens, T., Diepenbrock, W.* (2006). Integrated nitrogen management strategies to improve seed yielg, oil content and nitrogen efficiency of winter oilseed rapeseed (Brassica napus L.) Agriculture Ecosystems & Environment (117), 80-108.

11. *Reckleben, A. Y., Vosshenrich, H. H.* (2008). Getreideernte durch den Hochschnitt [Grain harvest by the high cut]. Getreide. (13) 2: 108-109. (in Germany).

12. *Statistical* yearbook of Lithania, (2013), 671.

13. *Šidlauskas, G. and Bernotas, S.* (2003). Some factors affecting seed yield of spring oilseed rapeseed (Brassica napus L.). Agronomy Research, 1 (2), 229-243.

14. *Špokas, L., Velička, R., Rimkevičienė, M., Marcinkevičienė, R.* (2005). Ripening dinamics and natural falling of spring rapeseed seeds. Vilnius. Agricultural Sciences. Nr. 3, 29-38. (in Lithania).

15. *Špokas, L., Velička, A., Marcinkevičienė, R., Domeika, R.* (2004). Optimization of the harvest time of summer rape by selection variety. Die Bodenkultur. Vienna. Bd. 55. H.3, 113-120. (in Germany).

16. *Zimmer, R. and Košutič, S.* (2006). Oil rapeseed seed harvesting season 2005 in Eastern Slavonia. Poljoprivredna tehnika. Agricultural engineering, 31 (3), 37-41. (in Slovenia).

Список літератури

1. *Rathke, G.-W., Behrens, T., Diepenbrock W.* Integrated nitrogen management strategies to improve seed yielg, oil content and nitrogen efficiency of winter oilseed rapeseed (Brassica napus L.). Agriculture Ecosystems & Environment. Nr.117. 2006. P. 80–108.

2. *Statistical* yearbook of Lithania. 2013. 671 p.

3. *Špokas, L. Velička, R., Rimkevičienė, M., Marcinkevičienė R.* Ripening dinamics and natural falling of spring rapeseed seeds. Agricultural Sciences. Nr. 3. 2005. P. 29–38.

4. *Špokas, L., Velička, A., Marcinkevičienė, R., Domeika R.* Optimierung des Erntezeitpunktes von Sommerraps durch die Sortenwahl. Die Bodenkultur. Bd. 55, H.3. 2004. P. 113–120.

5. *Morgan, C. L., Bruce, D. M., Child, R., Ladbrooke, Z. L., Arthur, A. E.* Genetic variation for pod shatter resistance among lines of oilseed rapeseed developed from synthetic B. napus. Field crops Research Nr. 58. 1998. P. 153–165.

6. *Šidlauskas, G., Bernotas, S.* Some factors affecting seed yield of spring oilseed rapeseed (Brassica napus L.). Agronomy Research. 2003. Nr. 1(2). P. 229–243.

7. *Pahkala, K., Sankari, H.* Shatter loss as a result of pod shatter in spring rapeseed and spring turnip rapeseed in Finland. Agrikultural and food scince in Finland. 2001. Vol. 10. P. 209–216.

8. *Price, J., S., Hobson, R. N., Neale, M. A., Bruce, D. M.* Shatter losses in Commercial Harvesting of Oilseed Rape. Journal of Agricultural Engineering Research. 1996. (65), 3. P. 183–191.

9. *Rademacher, T.* Methodology for measuring of quality and loss-throughput behavior for combine harvesters under field conditions. VDI-MEG Kolloquium Landtechnik. Mähdrescher. 2003. 40, P. 83–94.

10. *Rathke, G.-W., Behrens, T., Diepenbrock, W.* Integrated nitrogen management strategies to improve seed yielg, oil content and nitrogen efficiency of winter oilseed rapeseed (Brassica napus L.) Agriculture Ecosystems & Environment. 2006. 117. P. 80–108.

11. *Reckleben, A. Y., Vosshenrich, H. H.* Getreideernte durch den Hochschnitt [Grain harvest by the high cut]. Getreide. 2008. (13) 2. P. 108–109.

12. *Statistical* yearbook of Lithania, 2013, 671 p.

13. *Šidlauskas, G. and Bernotas, S.* Some factors affecting seed yield of spring oilseed rapeseed (Brassica napus L.). Agronomy Research, 2003. 1 (2), P. 229–243.

14. *Špokas, L., Velička, R., Rimkevičienė, M., Marcinkevičienė, R.* Ripening dinamics and natural falling of spring rapeseed seeds. Vilnius. Agricultural Sciences. 2005. Nr. 3. P. 29–38.

15. *Špokas, L., Velička, A., Marcinkevičienė, R., Domeika, R.* Optimization of the harvest time of summer rape by selection variety. Die Bodenkultur. Vienna. 2004. Bd. 55. H.3, P. 113–120.

16. *Zimmer, R. and Košutič, S.* Oil rapeseed seed harvesting season 2005 in Eastern Slavonia. Poljoprivredna tehnika. Agricultural engineering, 2006. 31 (3). P. 37–41.

ЗНИЖЕННЯ ВТРАТ НАСІННЯ І ВИТРАТА ПАЛИВА У ВРОЖАЮ РІПАКУ

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Анотація. Ріпаку збір урожаю починається в Прибалтиці, як тільки вологість насіння знижується до 12%. В той час як зміна вологості насіння не впливає на короткочасні опади, тривалі опади призводить до Ка. 2% збільшення вмісту вологи. Висока 0,2 м стерні озимого ріпаку припадає на частку 49.87% у загальній стовбурної маси. Її вологість становить 10.39% вище, ніж інша частка стовбурної маси. Збільшення висоти стерні до 0,3 м приводить до зменшення 15.52% в стовбурі маса подається в комбайні, і зниження 1.79% вологості маси стебла. У цьому випадку, витрата палива на гектар ріпаку намолочено буде нижче на 2,74 л, а на тонну обмолоченого зерна – на 0,27 л. Зв'язок між швидкістю ріпаку годувати в комбайні, зруйнувати втрати від розділення і очищення соломи, полови, і витрата палива на тонну обмолоченого Насіння був знайдений. Граничний розмір насіння ріпаку годувати в комбайні досягається, коли витрата палива на тонну обмолоченого насіння припинив зниження, але зруйнувати втрати соломи розділення і очищення полови-це ще в межах допустимого діапазону. У разі озимого ріпаку заготовка під обробку умови, витрата палива на тонну обмолоченого насіння варіювалася від 2,5 до 6,5 л, а у випадку раціональних вартість насіння ріпаку кормової комбайн, витрата палива на тонну обмолоченого насіння доїхати 2.93±0,23 л.

Ключові слова: зернозбиральний комбайн, ріпак, витрата палива, втрати зерна, пропускна здатність.

СНИЖЕНИЕ ПОТЕРЬ СЕМЯН И РАСХОД ТОПЛИВА В УРОЖАЕ РАПСА

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Аннотация. Рапса сбор урожая начинается в Прибалтике, как только влажность семян снижается до 12%. В то время как изменение влажности семян не влияет на кратковременные осадки, продолжительные осадки приводит к Ка. 2% увеличение содержания влаги. Высокая 0,2 м стерни озимого рапса приходится на долю 49.87% в общей стволовой массы. Ее влажность составляет 10.39% выше, чем остальная доля стволовой массы. Увеличение высоты стерни до 0,3 м приводит к уменьшению 15.52% в стволе масса подается в комбайне, и снижение 1.79% влажности стебля массы. В этом случае, расход топлива на гектар намолочено рапса будет ниже на 2,74 л, а на тонну обмолоченного зерна – на 0,27 л. Связь между скоростью рапса кормить в комбайне, разрушить потери от разделения и очистки соломы мякины, и расход топлива на тонну обмолоченного Семена был найден. Предельный размер семян рапса кормить в комбайне достигается, когда расход топлива на тонну обмолоченного семена прекратил снижение, но разрушить потери из соломы разделения и очистки плевел-это еще в пределах допустимого диапазона. В случае озимого рапса заготовка под обработку условия, расход топлива на тонну обмолоченного семена варьировалась от 2,5 до 6,5 л, а в случае рациональных стоимость семян рапса кормовой комбайн, расход топлива на тонну обмолоченного семена доехать 2.93±0,23 л.

Ключевые слова: зерноуборочный комбайн, рапс, расход топлива, потери зерна, пропускная способность.